Soil and Production Responses in Integrated Crop–Livestock Systems

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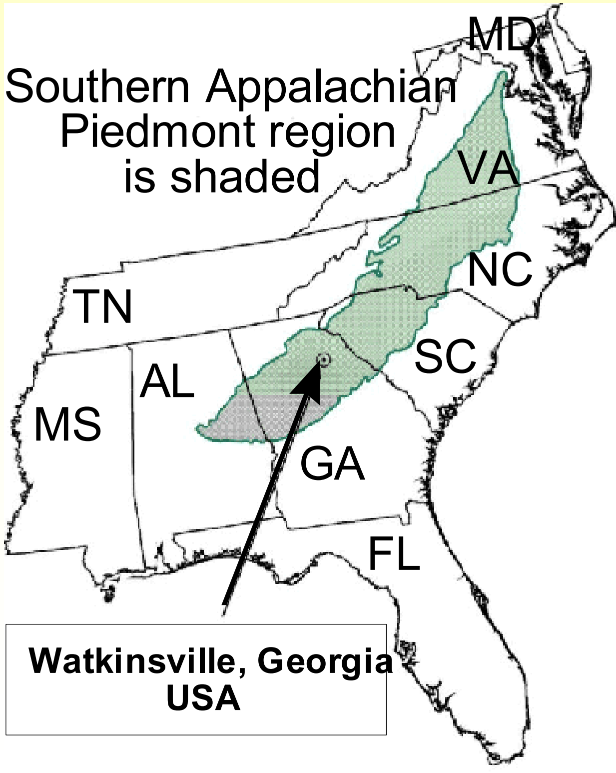
Ecologist



Sustainable Agricultural Systems

1. **Specialization**, based on considerations of:
   - Climate
   - Socioeconomics
   - Infrastructure
   - Markets

Specialized agricultural system

Chicago Board of Trade

Leading to a focus typically on the most profitable system possible without high regard to other factors

Or most traditional system that fits climate/infrastructure domain of region without high regard to other factors

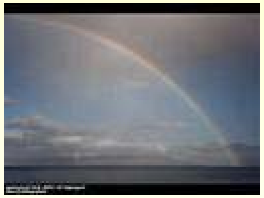
Sustainable Agricultural Systems

2. **Integration,** based on considerations of:
    - Climate
    - Socioeconomics
    - Infrastructure
    - Markets
    - Natural capital
    - Environmental impacts

Integrated agricultural system





Leading to diverse agricultural enterprises to balance production and economic gains with minimal negative influence on the environment.

Typically, systems that rely on natural capital rather than purchased capital to maximize resource efficiency.

Agriculture in the Southeastern USA

The 11-state region has the following characteristics compared with totals for the USA:

- **15% of the total land area**
- **26% of farms**
- **12% of farmland**
- **38% of woodland on farms**
- **14% of cropland**
- **4% of pasture or rangeland**

75% of broiler chicken inventory
- **26% of layer chicken inventory**
- **21% of hog inventory**
- **16% of cattle inventory**
- **3% of sheep inventory**

- **68% of peanut (2.7 Mg ha^{-1})**
- **49% of cotton (0.7 Mg ha^{-1})**
- **15% of cut forage (4.9 Mg ha^{-1})**
- **11% of wheat (4.2 Mg ha^{-1})**
- **11% of soybean (2.0 Mg ha^{-1})**
- **5% of corn (6.3 Mg ha^{-1})**

Data from Census of Agric. (2002) Nat. Agric. Stat. Serv., USDA
(SE region included AL, AR, FL, GA, KY, LA, MS, NC, SC, TN, VA)

The Problem

Production

- ✓ Farms operating on marginal profit
- ✓ Economic vulnerability with specialized production
- ✓ High cost of fuel and nutrients
- ✓ Pest pressures becoming greater with monocultures
- ✓ To maintain yields, greater fossil fuel inputs needed

Environment

- ✓ Nutrient import / export discontinuity
- ✓ Pollution of water bodies due to poor nutrient cycling
- ✓ Soil erosion still occurring

A Solution

Integration could be beneficial:

- Agronomically
- Environmentally
- Economically

- Objectives -

- ✓ ***Quantify agronomic responses*** **of crops to tillage and cover crop management**
- ✓ ***Determine soil quality changes*** **following cropping of previous land in pasture**
- ✓ ***Estimate economics*** **of crop and livestock production**

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- Experimental design -

Tillage

X

Cropping System

X

Cover crop utilization

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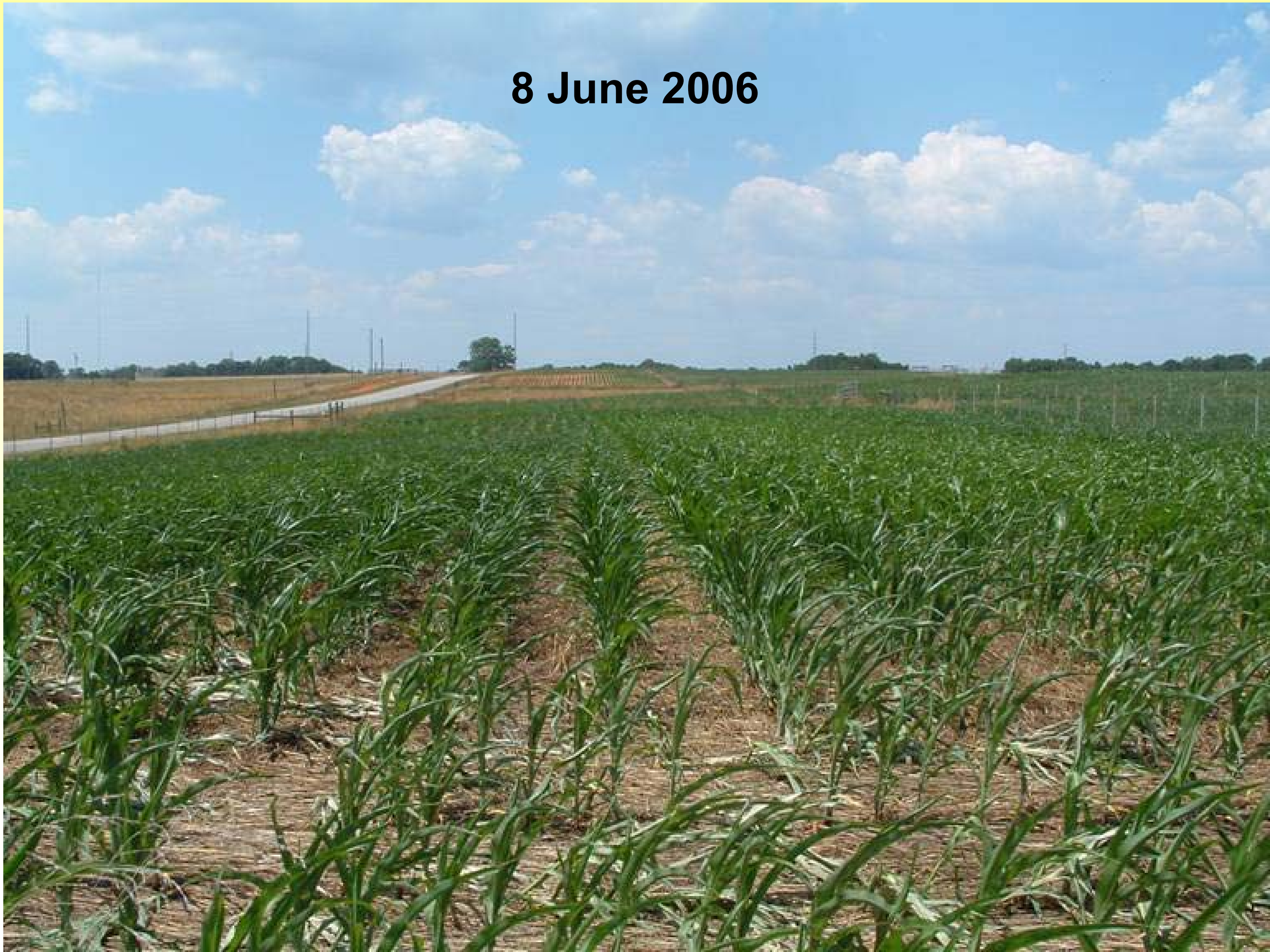
Wheat / pearl millet cropping system

Plot 7
Ungrazed exclosure

No tillage



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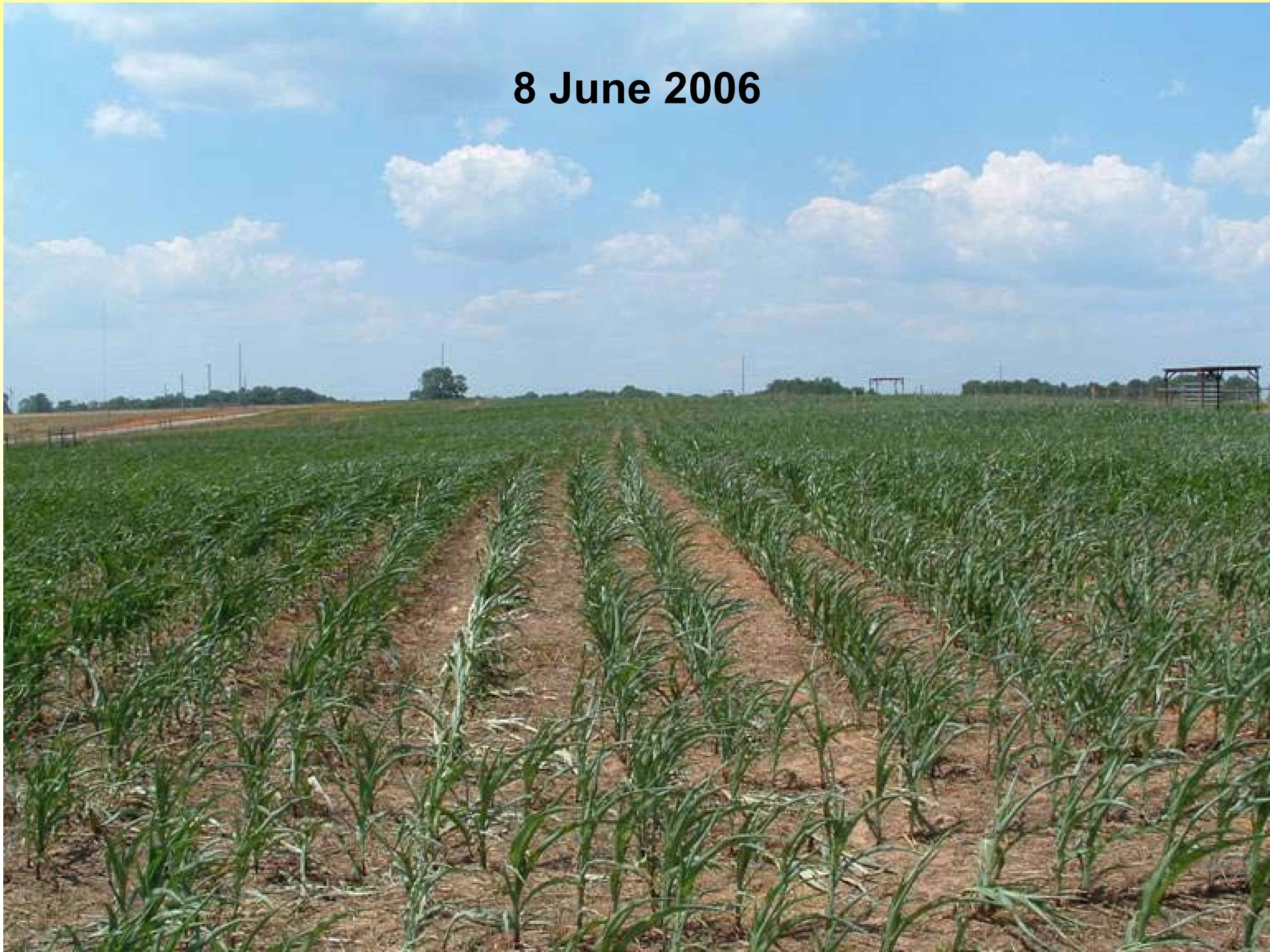
Wheat /
pearl millet
cropping
system

Plot 7
Grazed
paddock

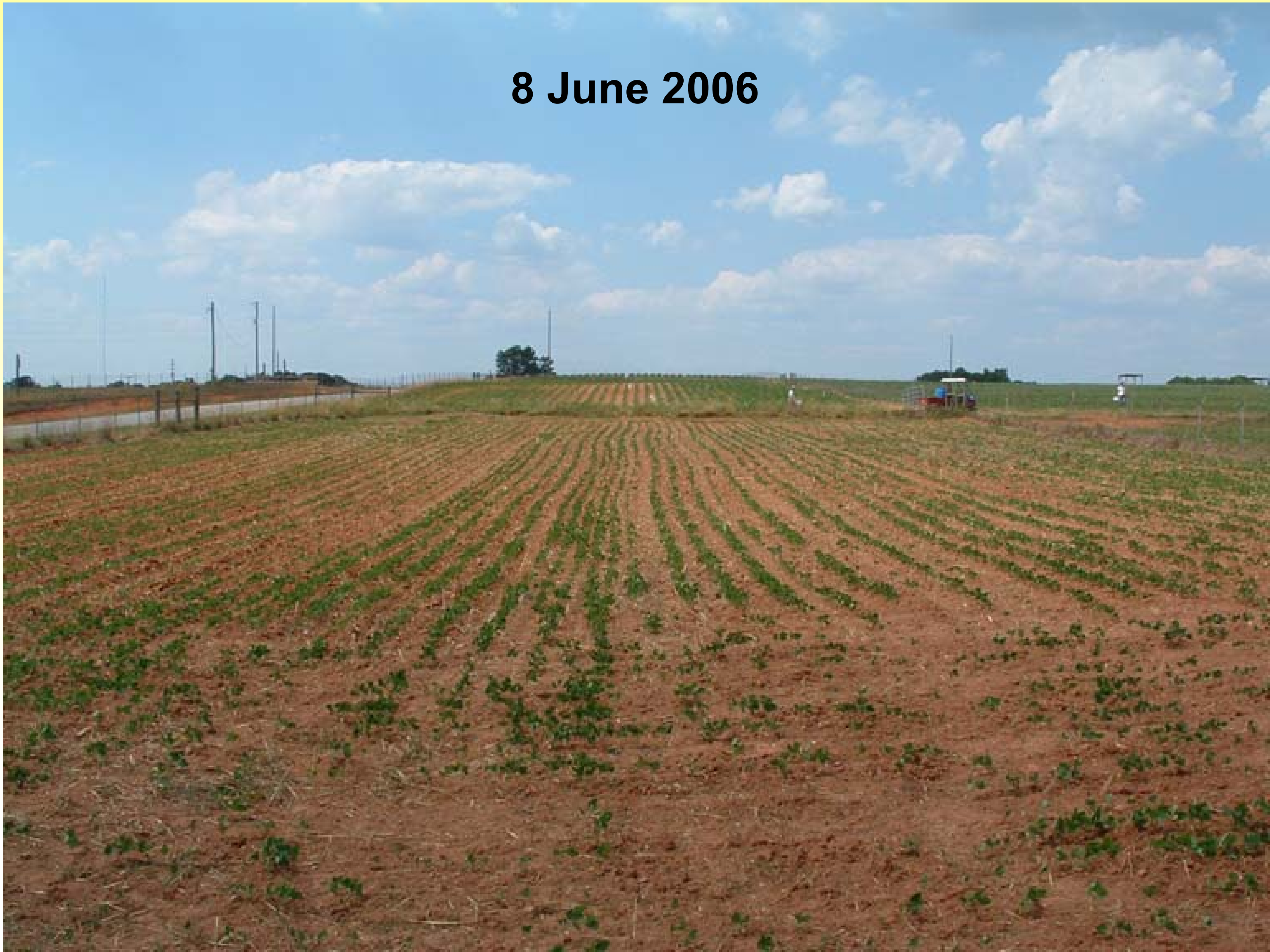
No
tillage



Corn / rye cropping system

Plot 11
Ungrazed exclosure

Disk tillage



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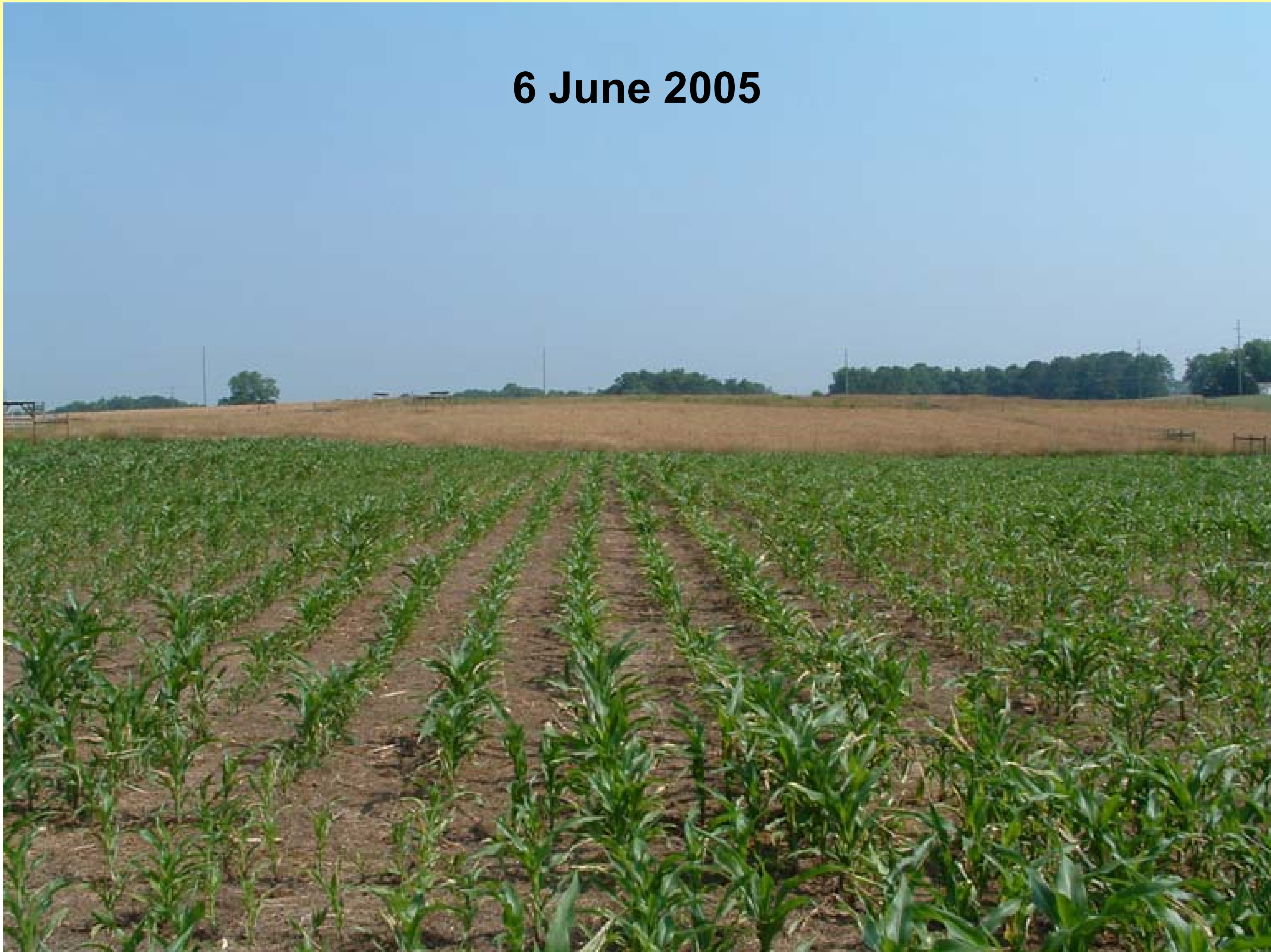
Corn / rye cropping system

Plot 10
Grazed paddock

No tillage



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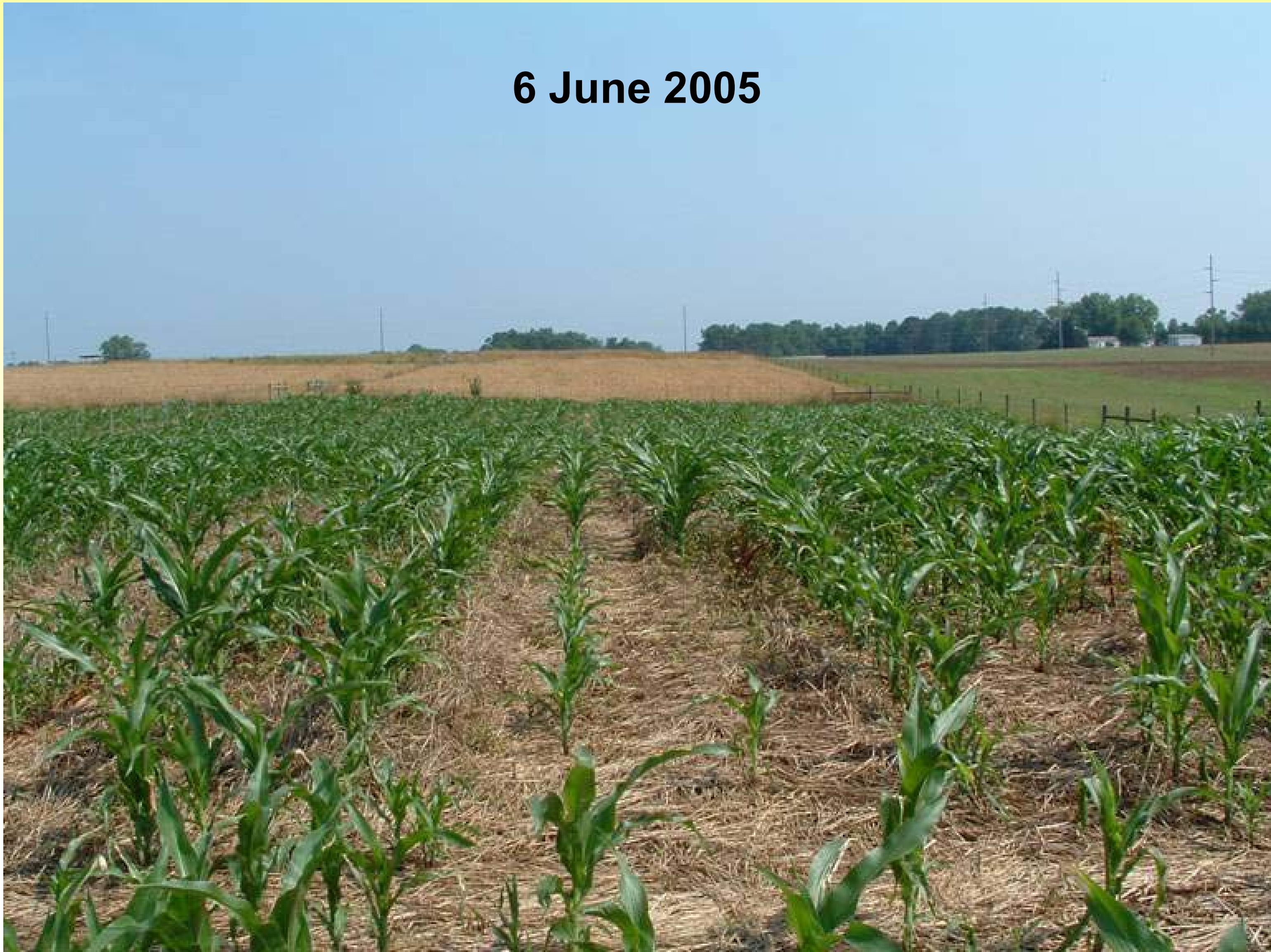
Corn /
rye
cropping
system

Plot 10
Ungrazed
exclosure

No
tillage



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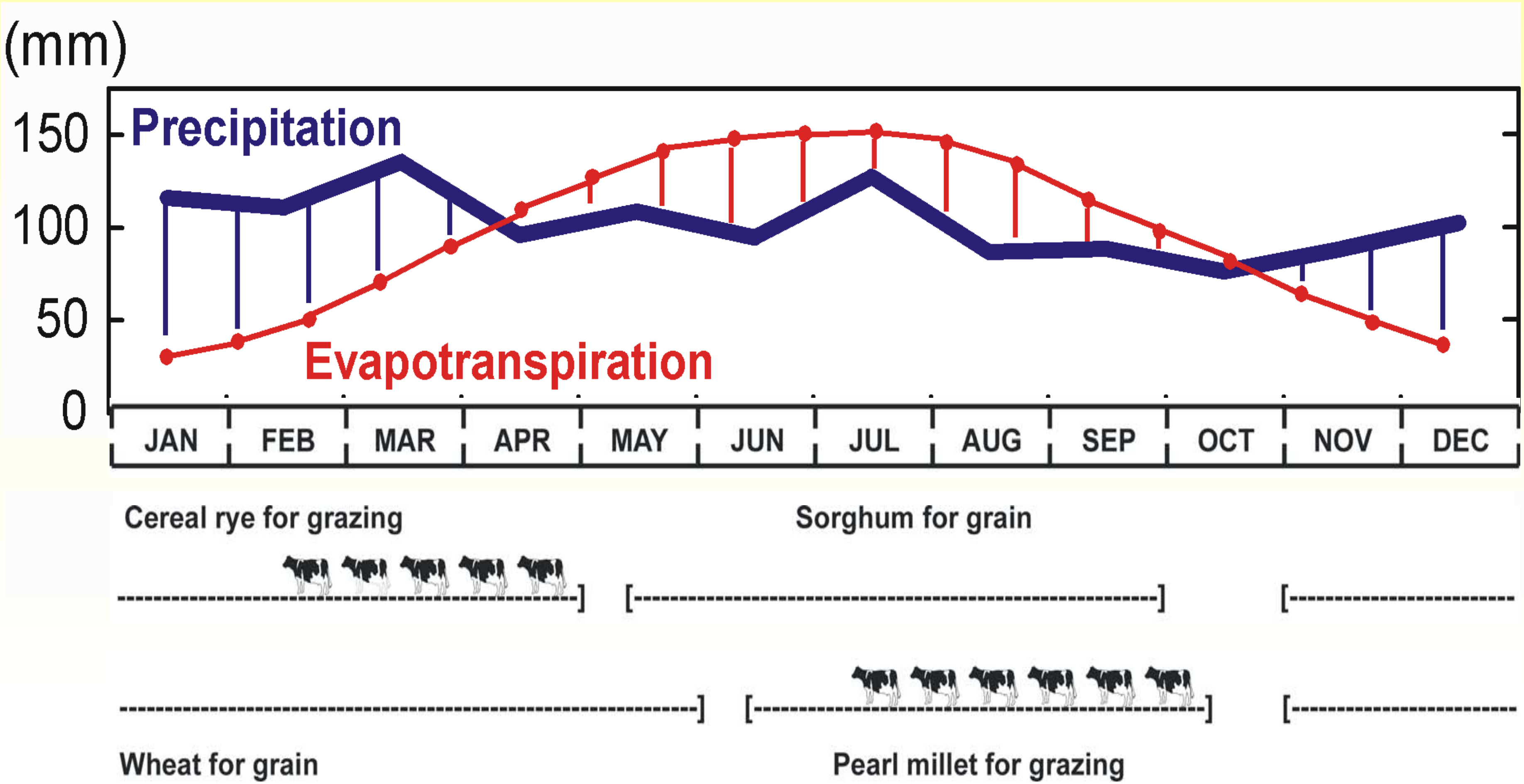
Seasonal conditions



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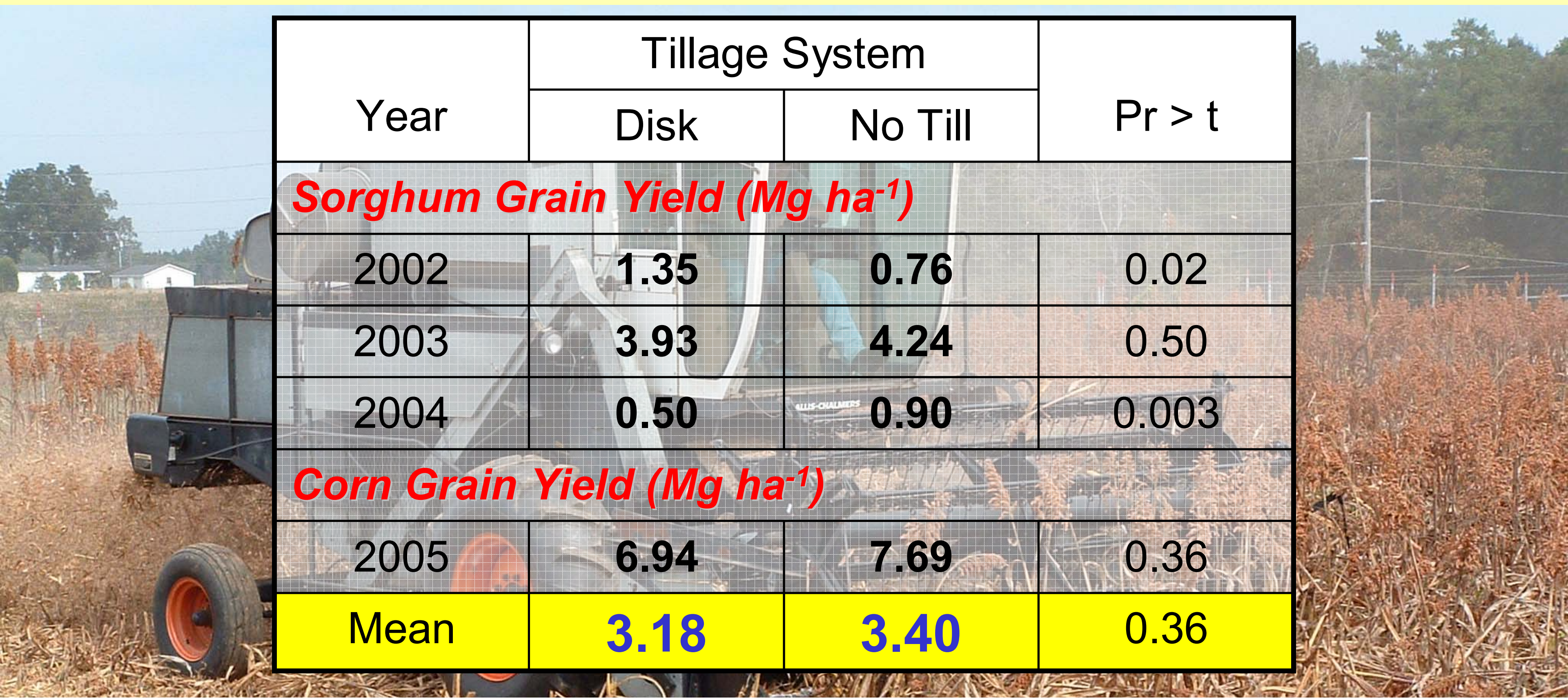
How did summer grain yield respond to tillage?



Year	Tillage System		Pr > t
	Disk	No Till	
Sorghum Grain Yield (Mg ha^{-1})			
2002	**1.35**	**0.76**	0.02
2003	**3.93**	**4.24**	0.50
2004	**0.50**	**0.90**	0.003
Corn Grain Yield (Mg ha^{-1})			
2005	**6.94**	**7.69**	0.36
Mean	**3.18**	**3.40**	0.36

Overall, no difference in yield between tillage systems

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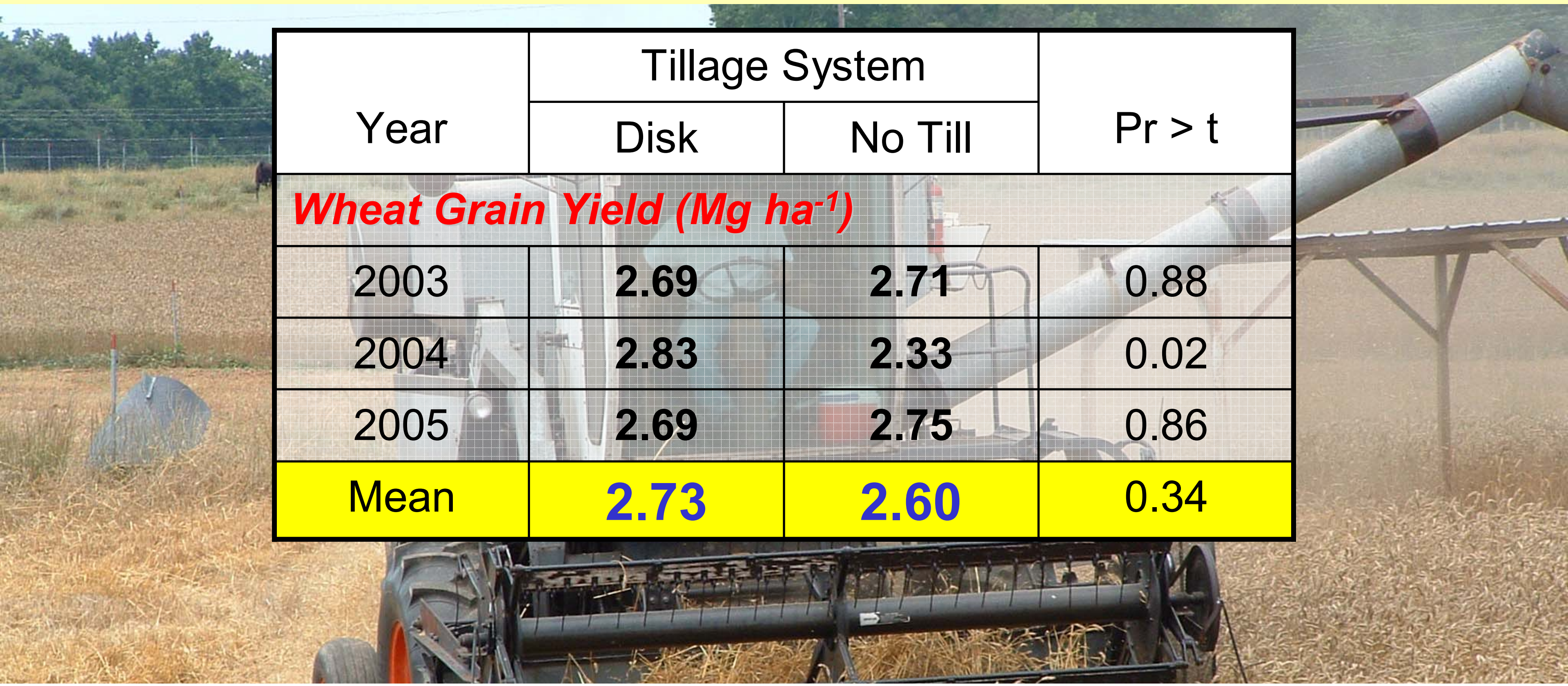
How did winter grain yield respond to tillage?



Year	Tillage System		Pr > t
	Disk	No Till	
Wheat Grain Yield (Mg ha^{-1})			
2003	**2.69**	**2.71**	0.88
2004	**2.83**	**2.33**	0.02
2005	**2.69**	**2.75**	0.86
Mean	**2.73**	**2.60**	0.34

Overall, no difference in yield between tillage systems

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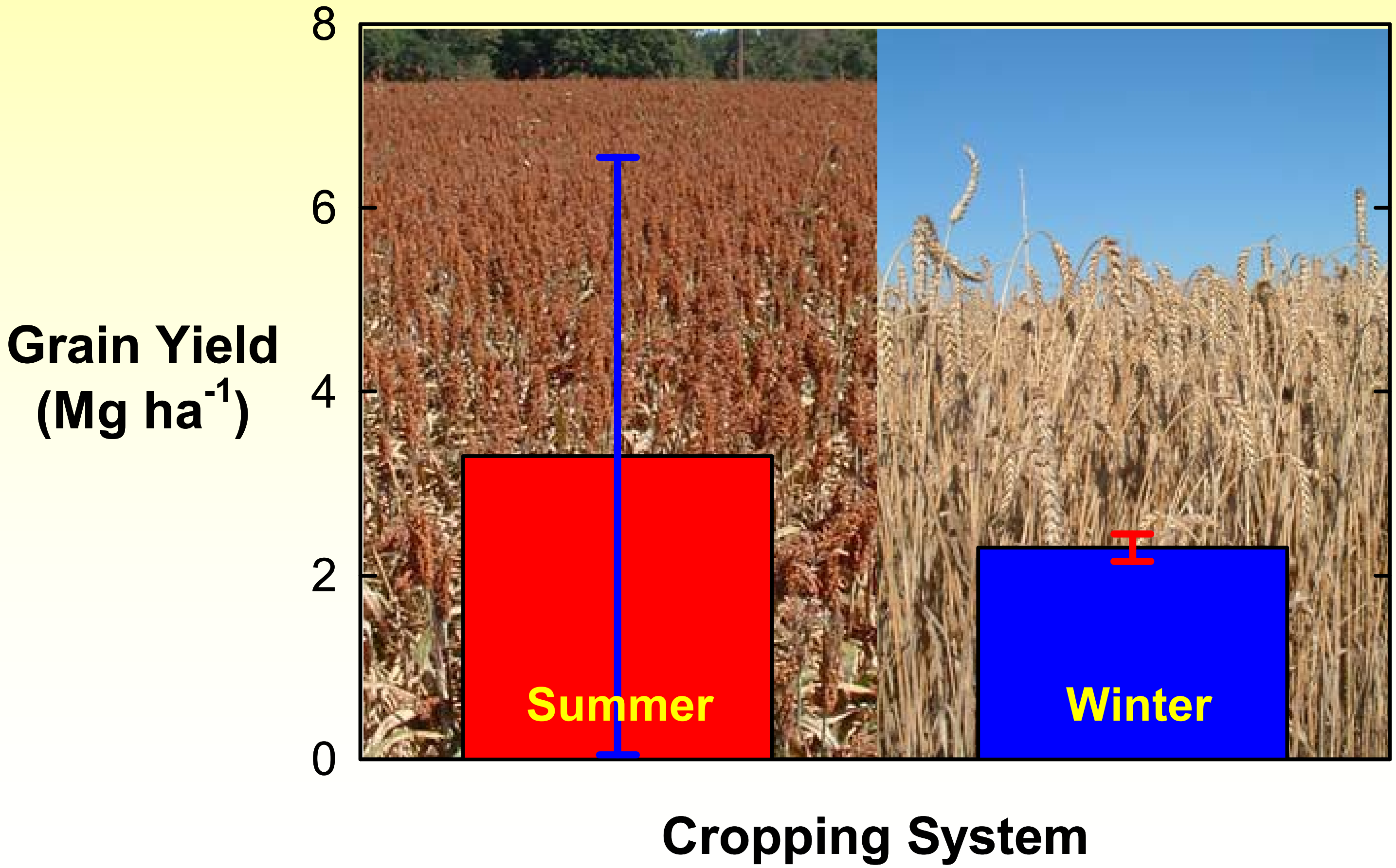
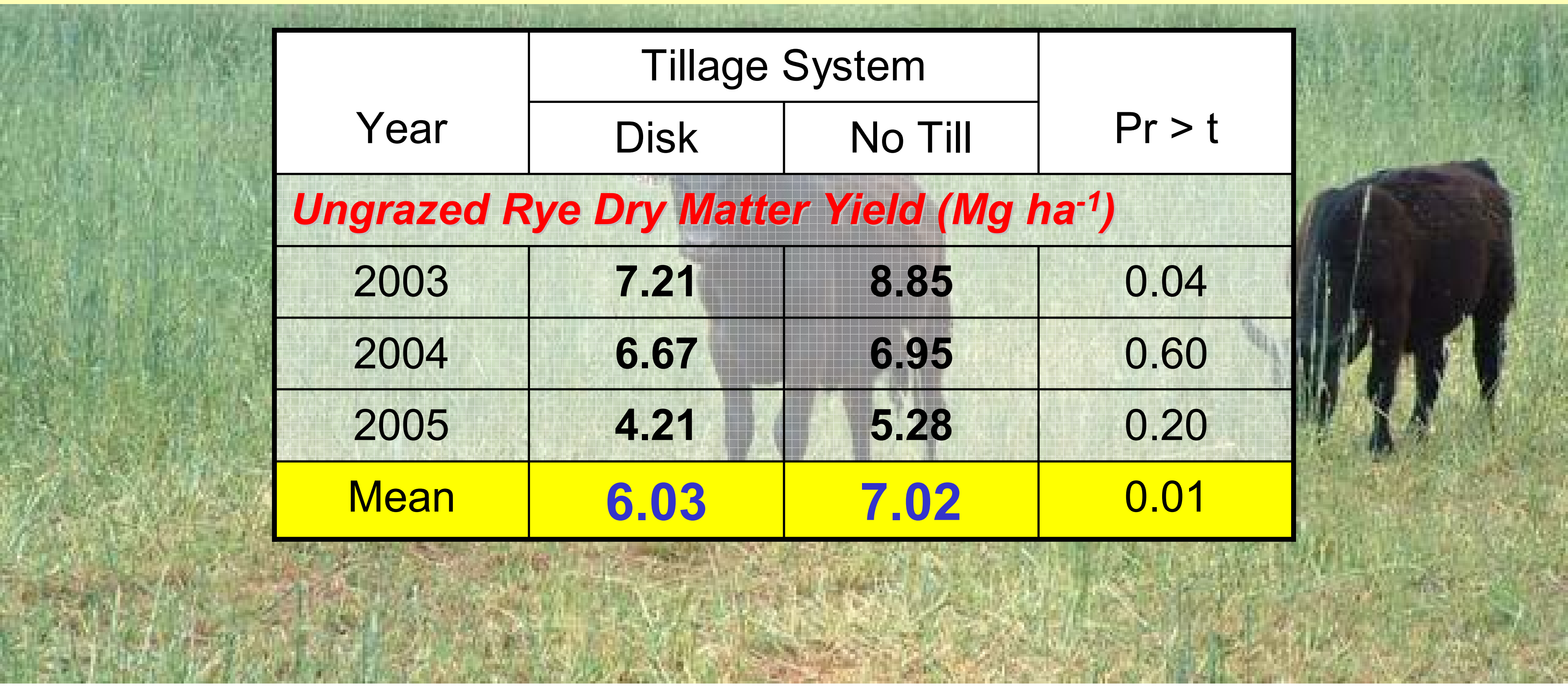
How productive and reliable were systems?



How did winter cover crop respond to tillage?



Year	Tillage System		Pr > t
	Disk	No Till	
Ungrazed Rye Dry Matter Yield (Mg ha^{-1})			
2003	**7.21**	**8.85**	0.04
2004	**6.67**	**6.95**	0.60
2005	**4.21**	**5.28**	0.20
Mean	**6.03**	**7.02**	0.01

NT improved cover crop growth compared with DT (16%)

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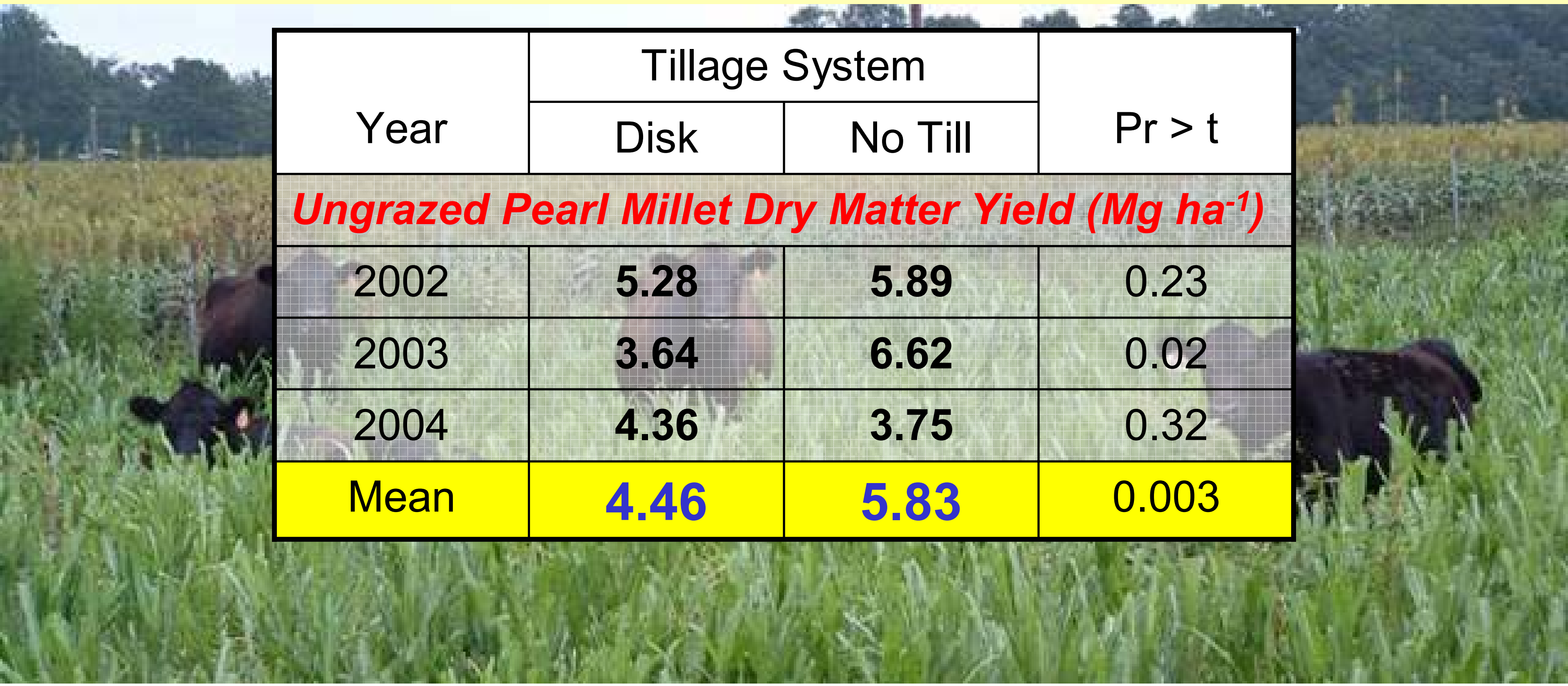
How did summer cover crop respond to tillage?



Year	Tillage System		Pr > t
	Disk	No Till	
Ungrazed Pearl Millet Dry Matter Yield (Mg ha^{-1})			
2002	**5.28**	**5.89**	0.23
2003	**3.64**	**6.62**	0.02
2004	**4.36**	**3.75**	0.32
Mean	**4.46**	**5.83**	0.003

NT improved cover crop growth compared with DT (31%)

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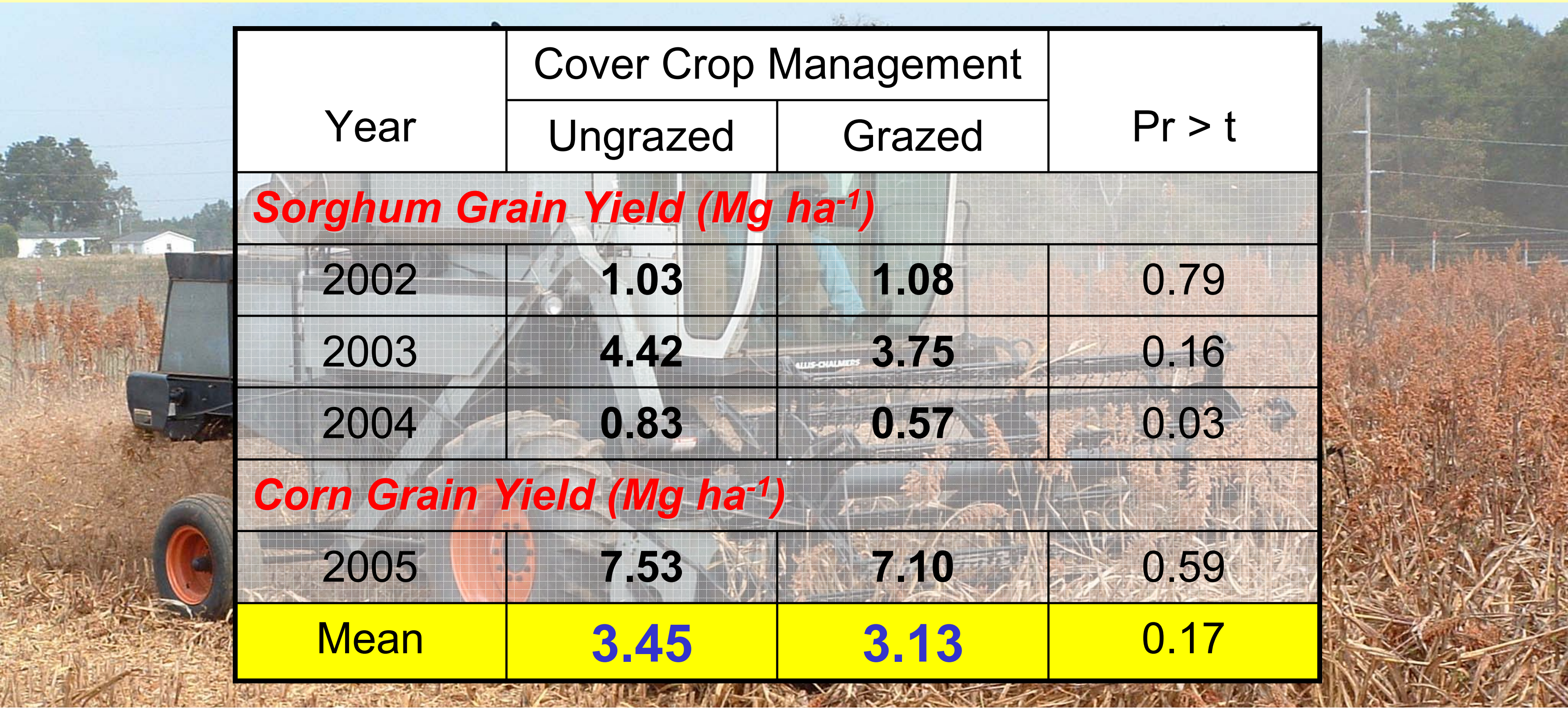
How did summer grain yield respond to cover crop mgmt?



Year	Cover Crop Management		Pr > t
	Ungrazed	Grazed	
Sorghum Grain Yield (Mg ha^{-1})			
2002	**1.03**	**1.08**	0.79
2003	**4.42**	**3.75**	0.16
2004	**0.83**	**0.57**	0.03
Corn Grain Yield (Mg ha^{-1})			
2005	**7.53**	**7.10**	0.59
Mean	**3.45**	**3.13**	0.17

Overall, no difference in yield between cover crop systems

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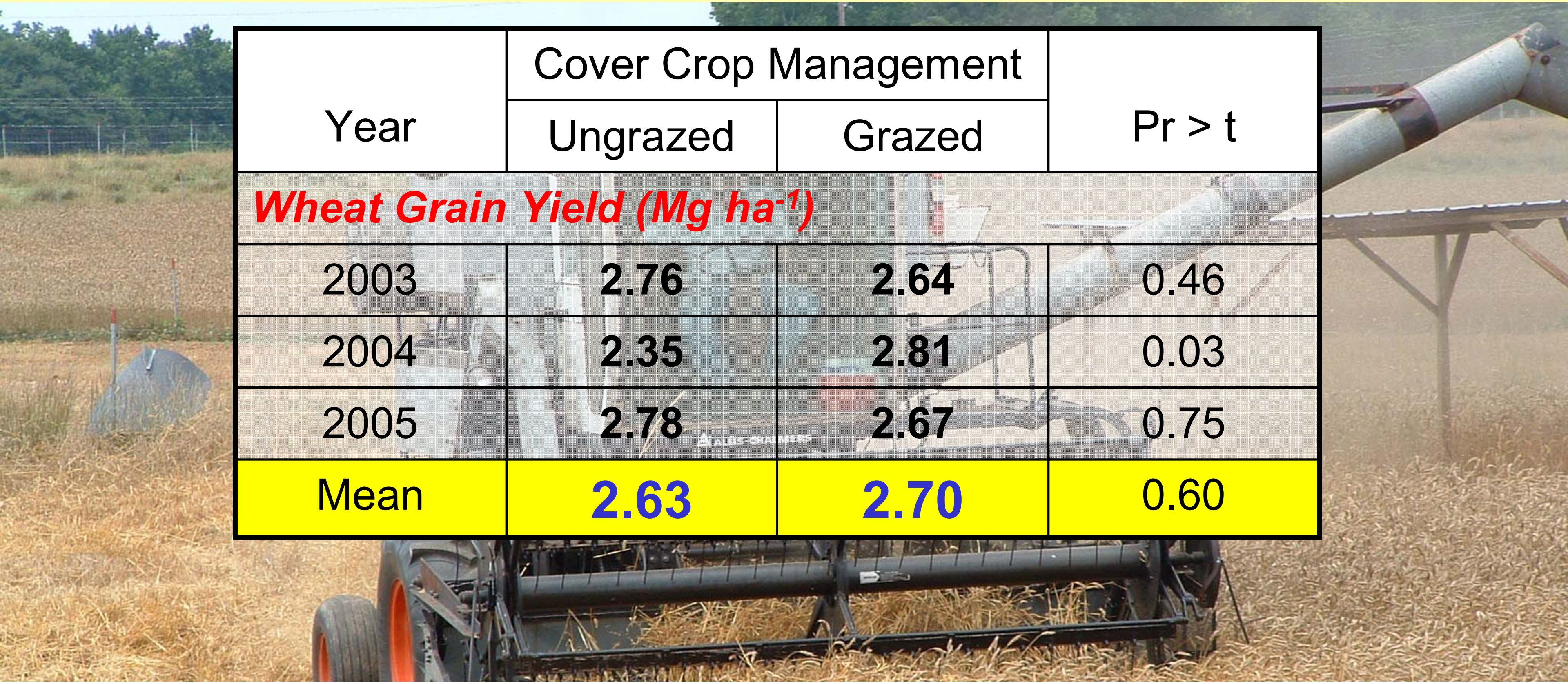
How did winter grain yield respond to cover crop mgmt?



Year	Cover Crop Management		Pr > t
	Ungrazed	Grazed	
Wheat Grain Yield (Mg ha^{-1})			
2003	**2.76**	**2.64**	0.46
2004	**2.35**	**2.81**	0.03
2005	**2.78**	**2.67**	0.75
Mean	**2.63**	**2.70**	0.60

Overall, no difference in yield between cover crop systems

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How did tillage affect livestock responses?

Year	Tillage System		Pr > t	Tillage System		Pr > t
	Disk	No Till		Disk	No Till	
Grazing Days (head days ha^{-1}) – Winter				***Summer***		
2002	--	--	--	518	455	0.03
2003	252	252	1.0	375	390	0.36
2004	301	539	0.07	400	400	1.0
2005	228	240	0.54	250	330	<0.001
Mean	260	344	0.04	386	394	0.27

More grazing days with NT than DT in winter (32%), but the same in summer.

More grazing days in summer than in winter (29%)

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How did tillage affect livestock responses?

Year	Tillage System		Pr > t	Tillage System		Pr > t
	Disk	No Till		Disk	No Till	
Daily Gain (kg head^{-1} d^{-1}) – Winter				**Summer**		
2002	**--**	**--**	--	**1.74**	**2.01**	0.14
2003	**1.90**	**2.25**	0.17	**1.49**	**1.72**	0.66
2004	**1.81**	**2.26**	0.25	**0.60**	**0.91**	0.28
2005	**0.62**	**1.36**	0.24	**2.01**	**1.95**	0.83
Mean	**1.44**	**1.96**	0.01	**1.46**	**1.65**	0.26

Greater cattle performance with NT than DT in winter (36%), but less difference in summer (13%).

Better performance in winter than in summer (10%)

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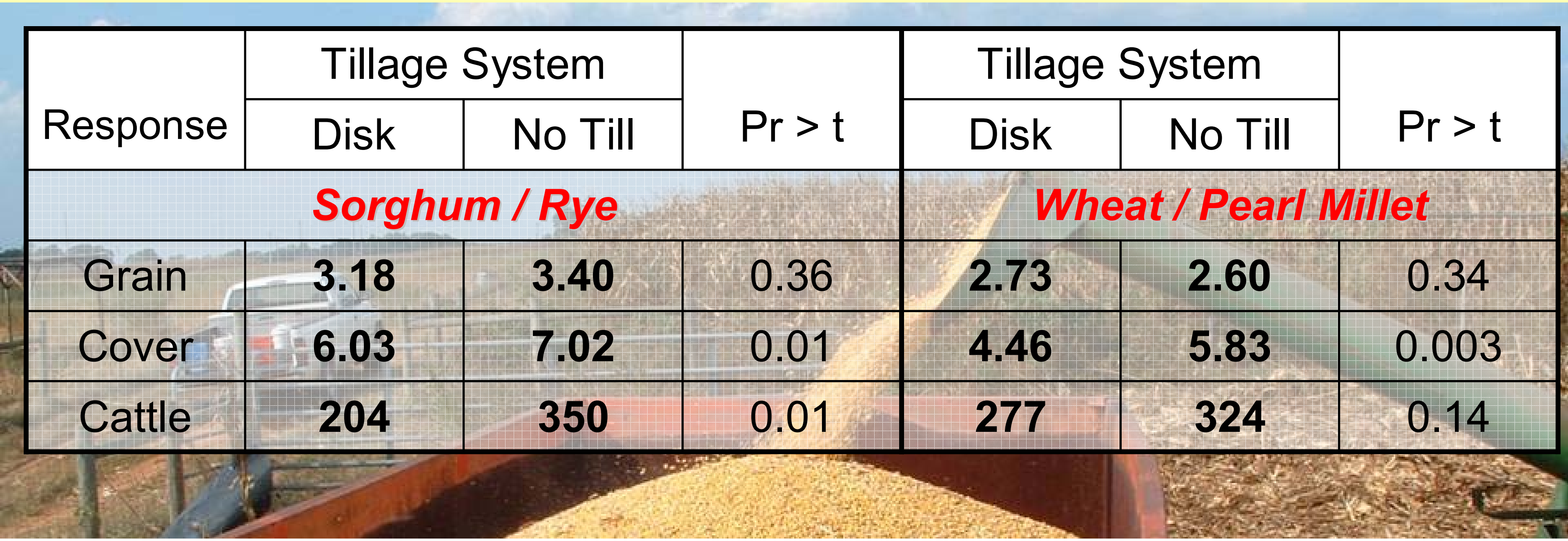
How did tillage affect livestock responses?

Year	Tillage System: Disk	Tillage System: No Till	Pr > t	Tillage System: Disk	Tillage System: No Till	Pr > t
Cattle Gain (kg ha^{-1}) – Winter				**Summer**		
2002	**--**	**--**	--	**452**	**456**	0.92
2003	**239**	**283**	0.17	**286**	**335**	0.64
2004	**298**	**604**	0.07	**120**	**181**	0.28
2005	**76**	**163**	0.13	**250**	**324**	0.11
Mean	**204**	**350**	0.01	**277**	**324**	0.14

Greater cattle gain with NT than DT in winter (72%), but less difference in summer (17%).

Greater cattle gain in summer than in winter (8%)

Summary of production responses to tillage system



Response	Tillage System		Pr > t	Tillage System		Pr > t
	Disk	No Till		Disk	No Till	
	Sorghum / Rye			***Wheat / Pearl Millet***		
Grain	**3.18**	**3.40**	0.36	**2.73**	**2.60**	0.34
Cover	**6.03**	**7.02**	0.01	**4.46**	**5.83**	0.003
Cattle	**204**	**350**	0.01	**277**	**324**	0.14

Grain production was unaffected by tillage system

Cover crop growth was enhanced with NT compared with DT in both systems, which led to greater cattle gain on rye

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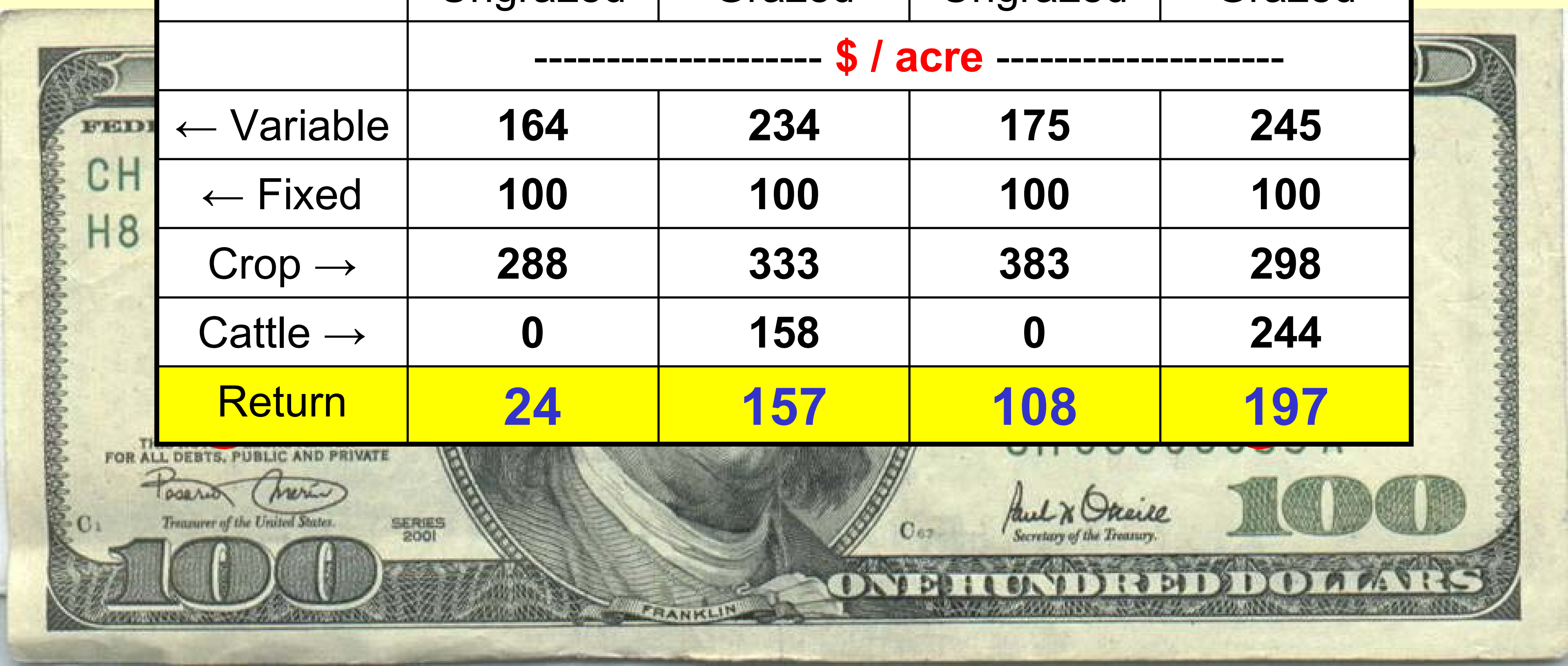
Will it pay to integrate cattle with cropping systems?

Response (Corn 2005)	Disk Tillage		No Tillage	
	Ungrazed	Grazed	Ungrazed	Grazed
	-------------------- $ / acre --------------------			
← Variable	**164**	**234**	**175**	**245**
← Fixed	**100**	**100**	**100**	**100**
Crop →	**288**	**333**	**383**	**298**
Cattle →	**0**	**158**	**0**	**244**
Return	**24**	**157**	**108**	**197**



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Soil Responses

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How has soil changed with tillage?

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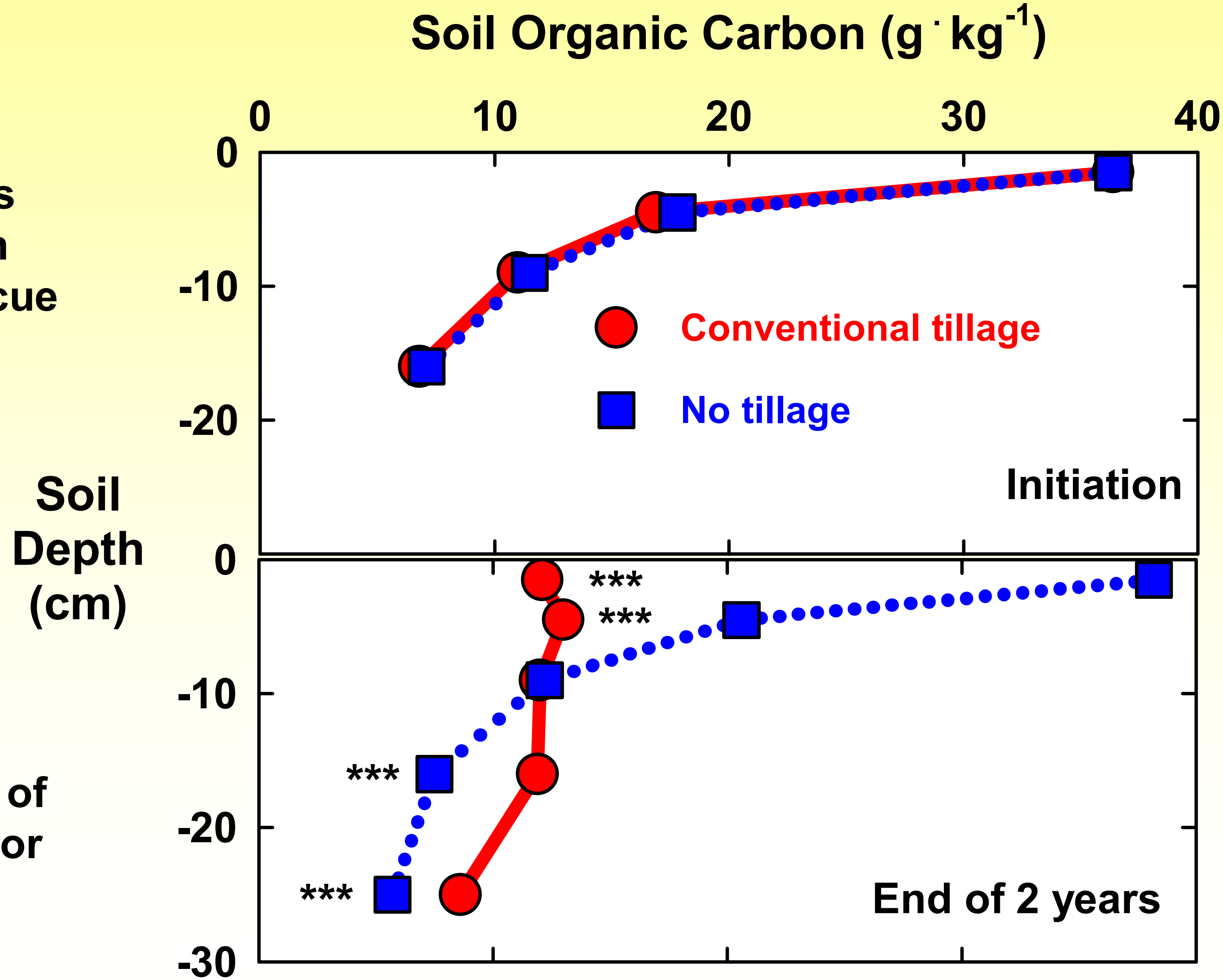
At initiation of this study, land was in long-term tall fescue pasture.

Land converted to cropping systems of wheat/pearl millet or sorghum/rye.



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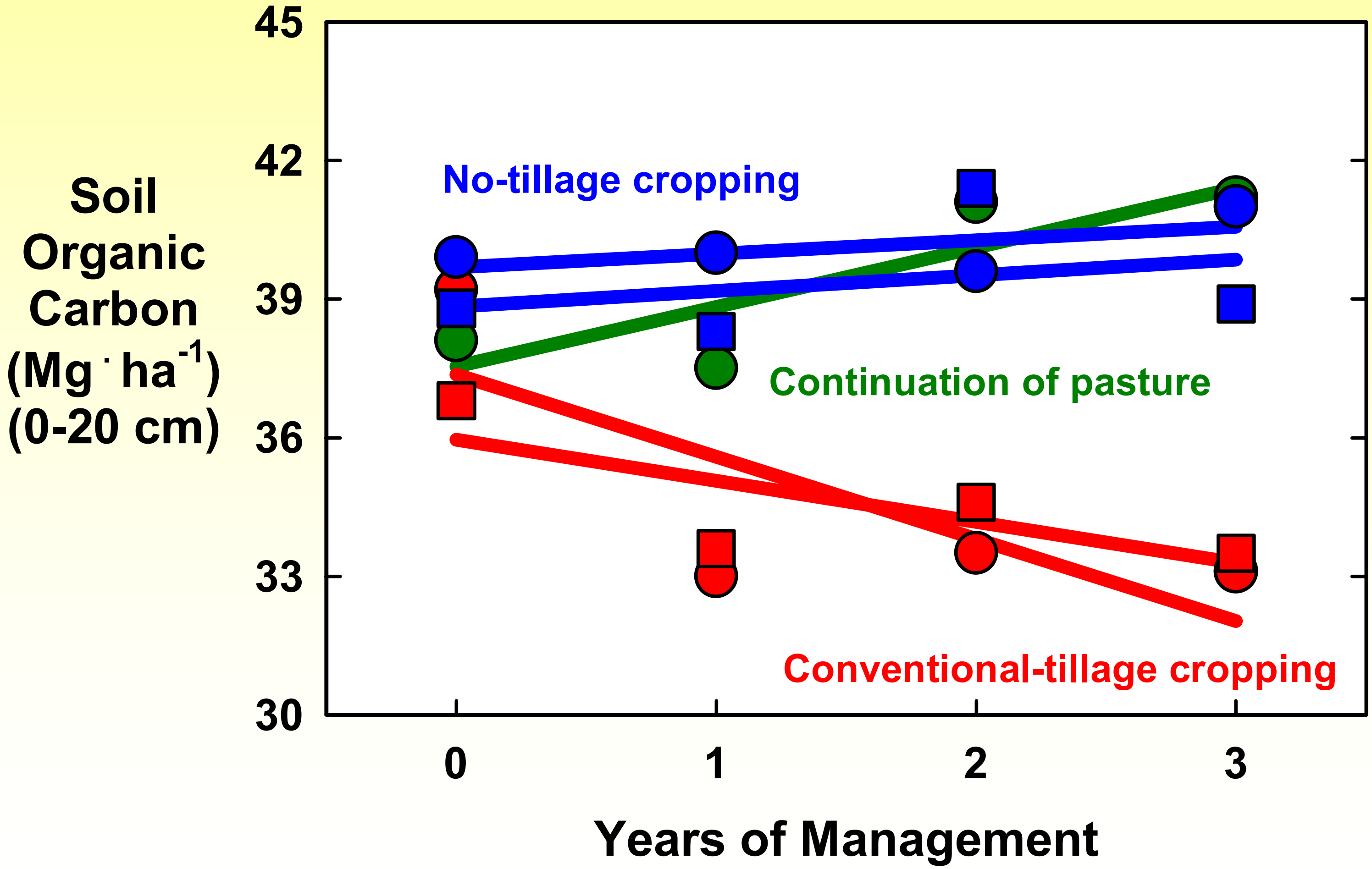

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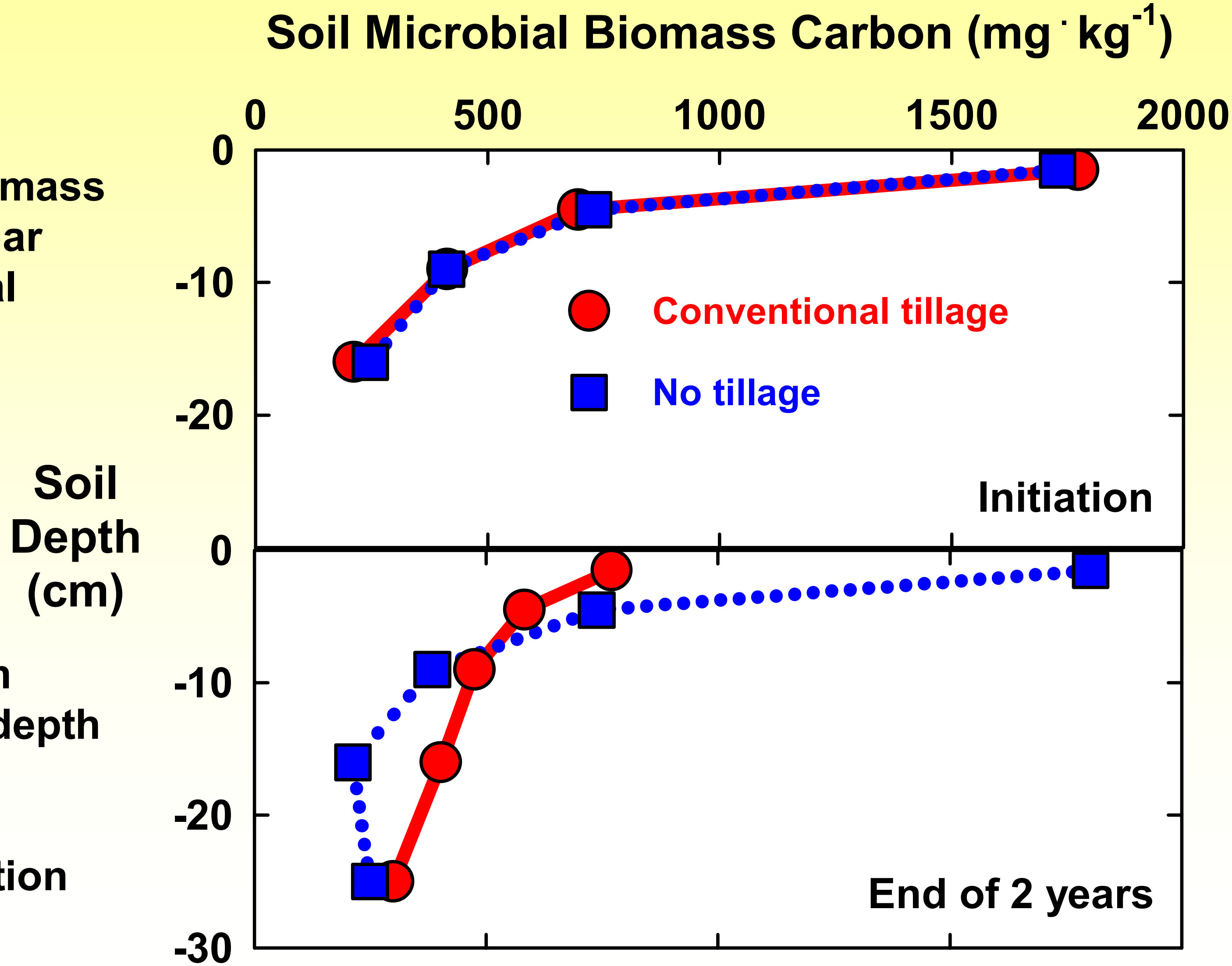
Soil microbial biomass C followed a similar pattern as for total organic C.

Relatively uniform distribution with depth under CT and maintenance of stratified distribution with NT.



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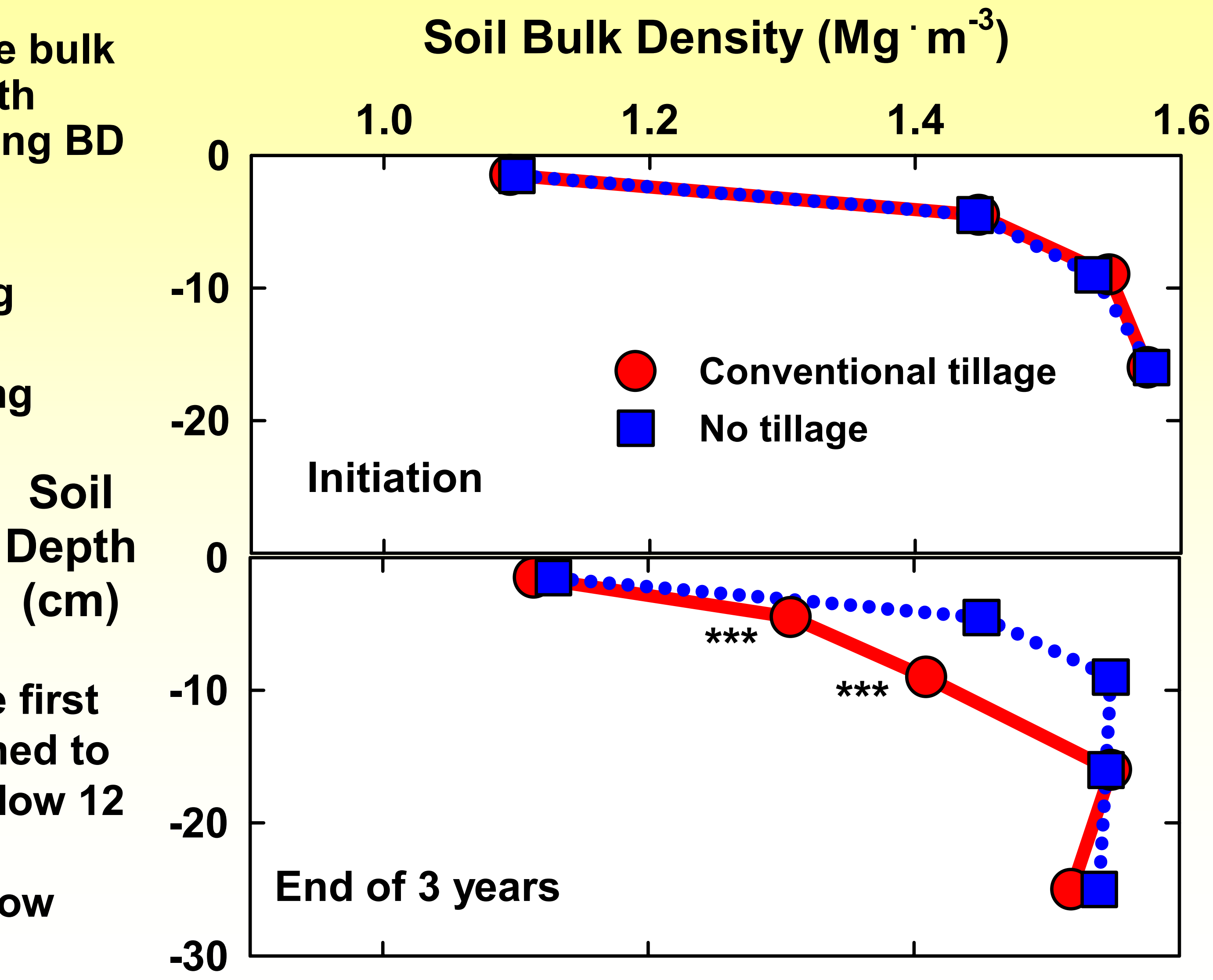
Initially low surface bulk density (BD) with rapidly increasing BD with depth

Moldboard plowing loosened soil initially following tillage

However, after the first year, BD returned to a high level below 12 cm because of switch to shallow disk tillage



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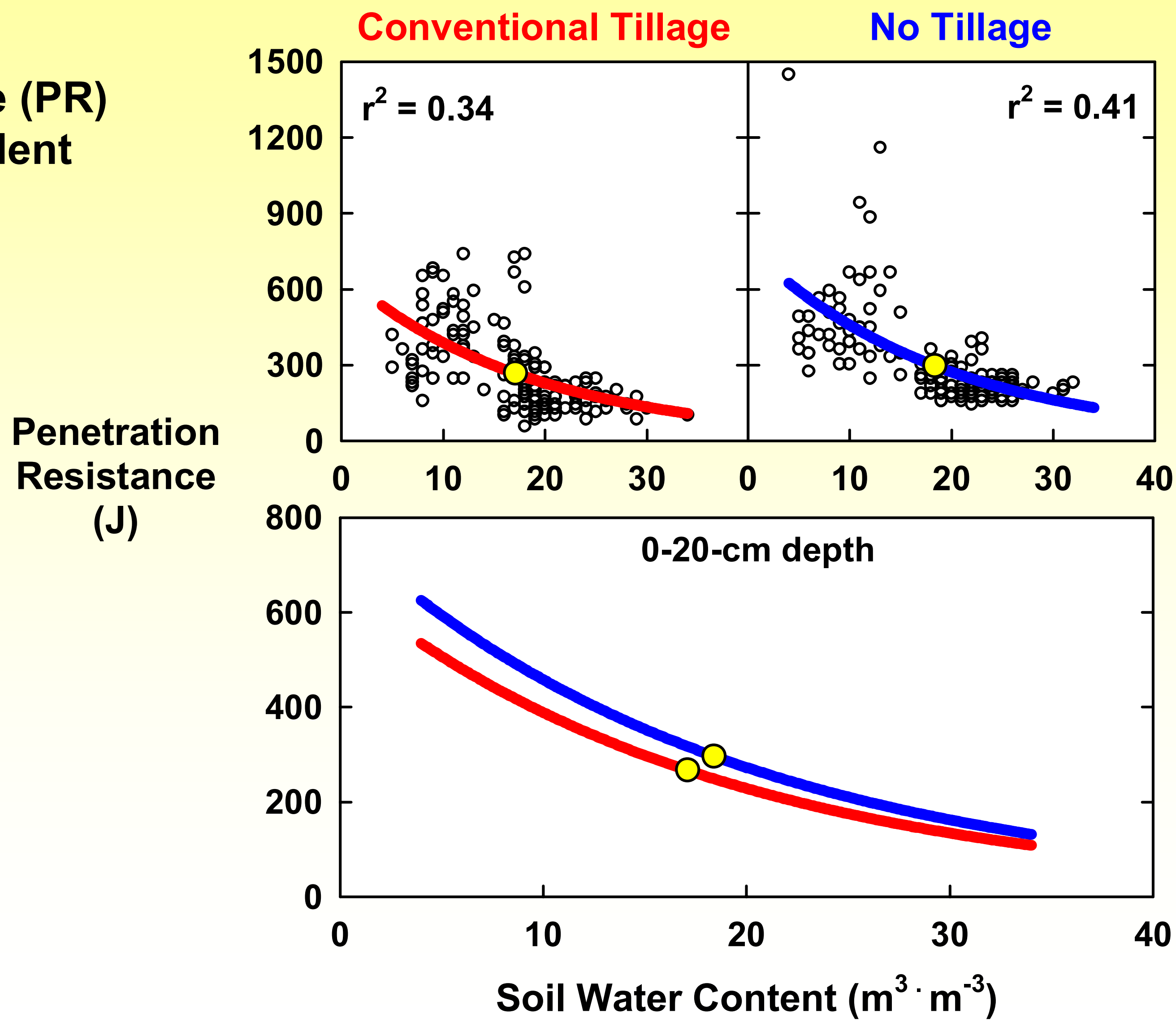
Penetration resistance (PR) was related to antecedent soil water content.

PR was: NT > CT especially when dry

Soil water content averaged:

CT = 17.1%

NT = 18.4%



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Water infiltration was also related to antecedent soil water content.

At low water content, infiltration was:

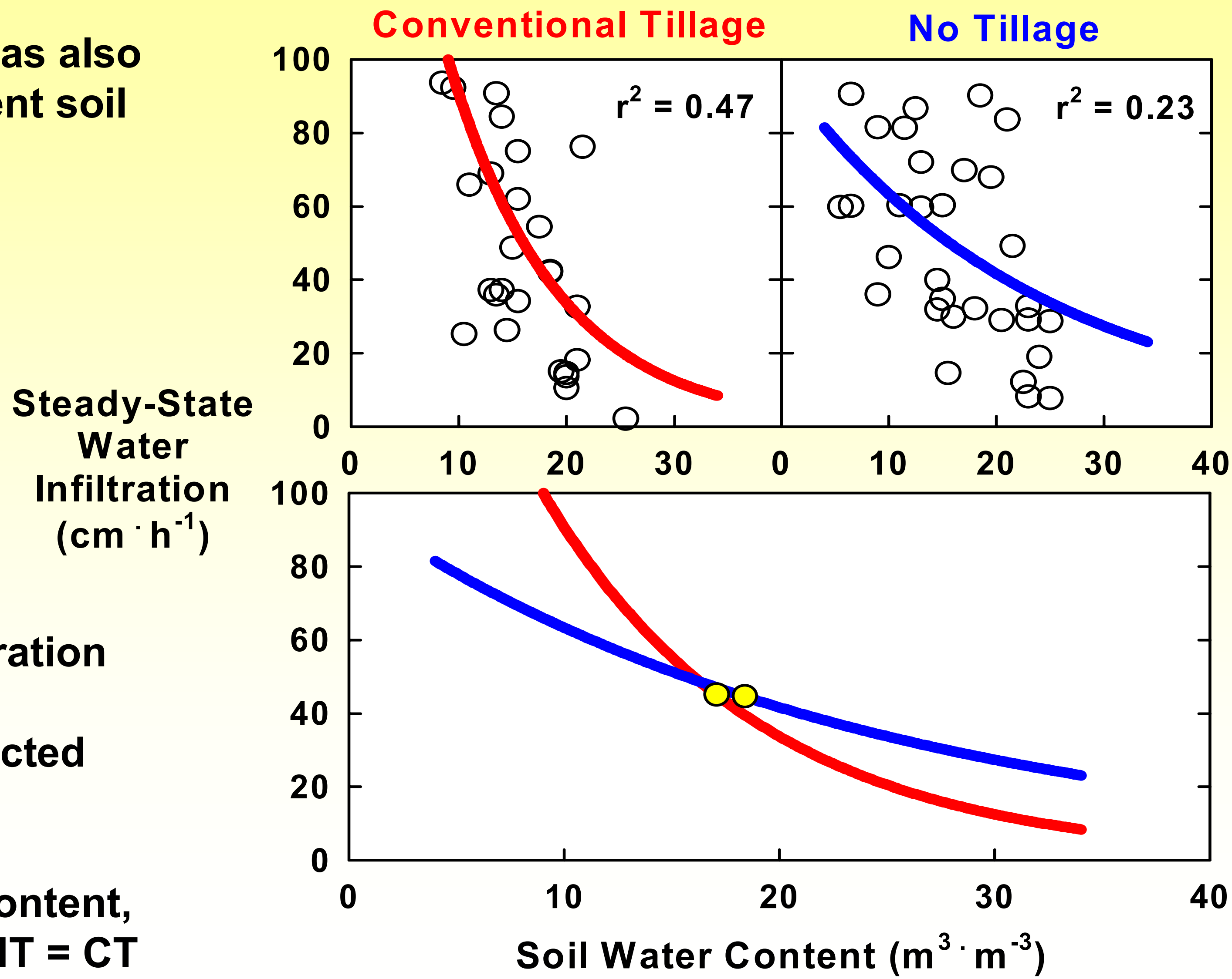
CT > NT

Likely due to large pores from tillage.

With wet soil, infiltration was: NT > CT

likely due to connected pores.

At average water content, infiltration was: NT = CT



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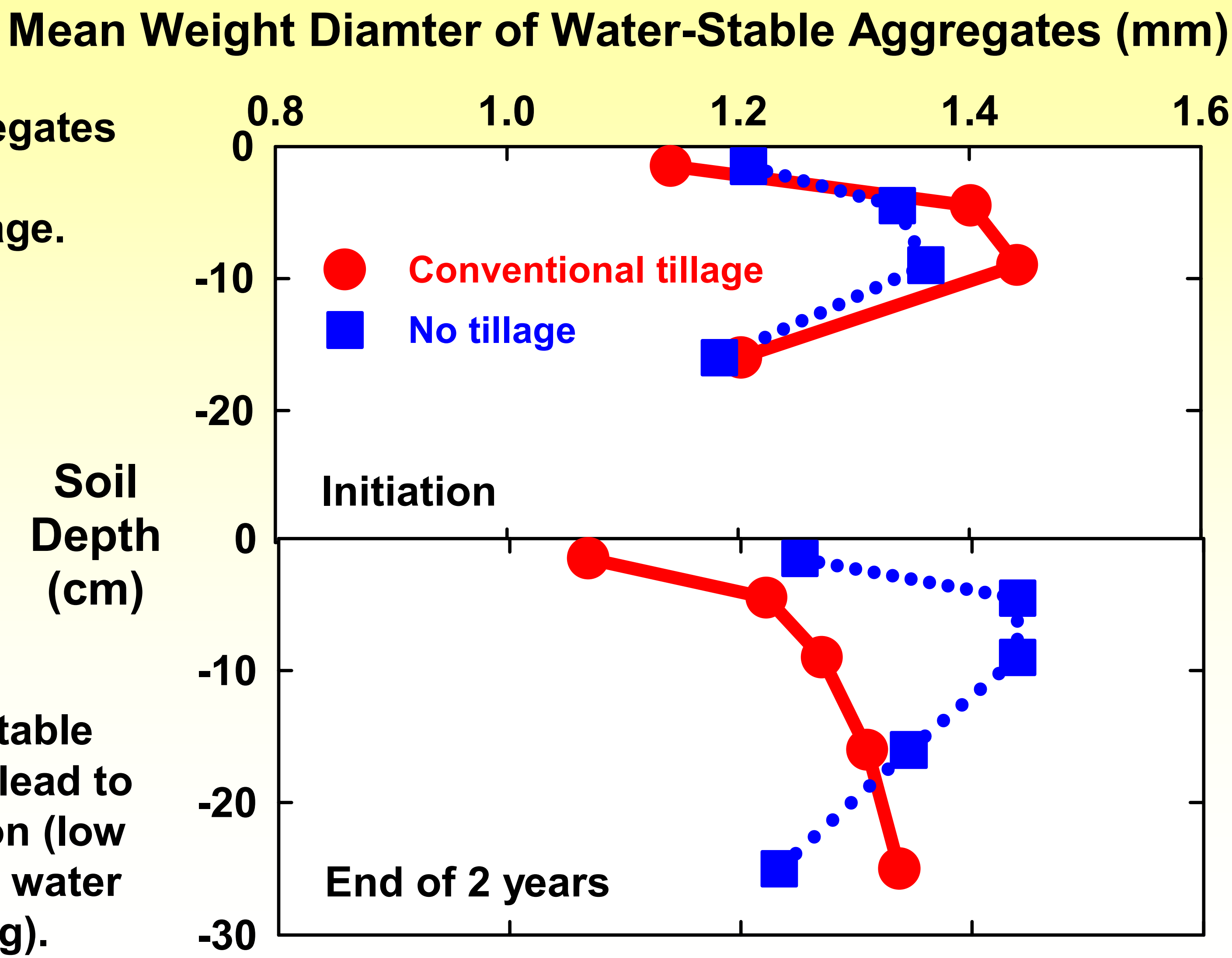
Water-stable aggregates became smaller following plow tillage.

Soil under NT maintained aggregate size with time.

Smaller and less stable aggregates would lead to surface degradation (low soil organic C, low water infiltration, crusting).



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How has soil changed with cover crop mgmt?

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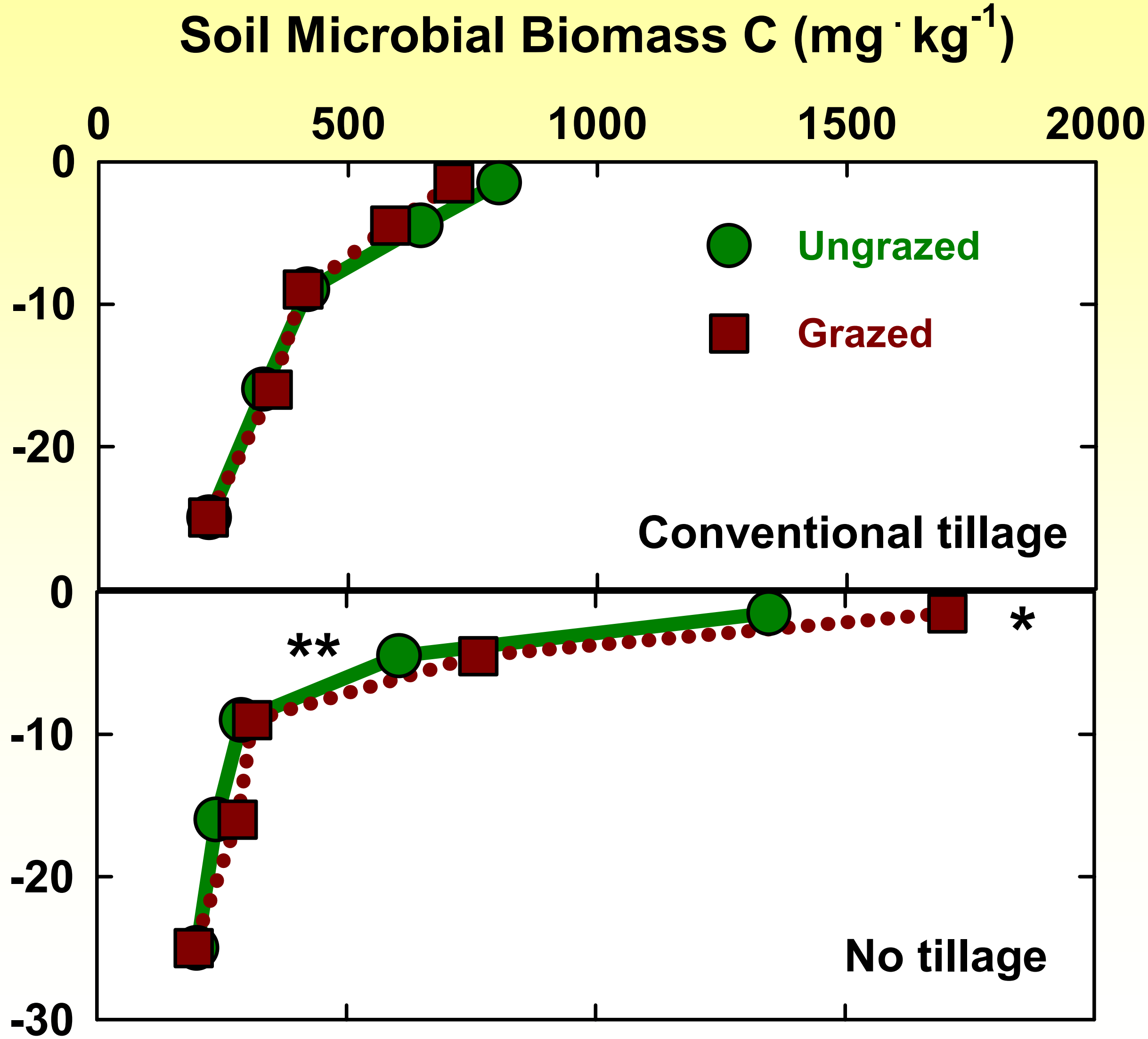
Whether cattle grazed cover crops or not, there was no impact on SMBC under CT.



Under NT, grazing improved SMBC within the surface 6 cm of soil probably due to plant processing through animal digestion.

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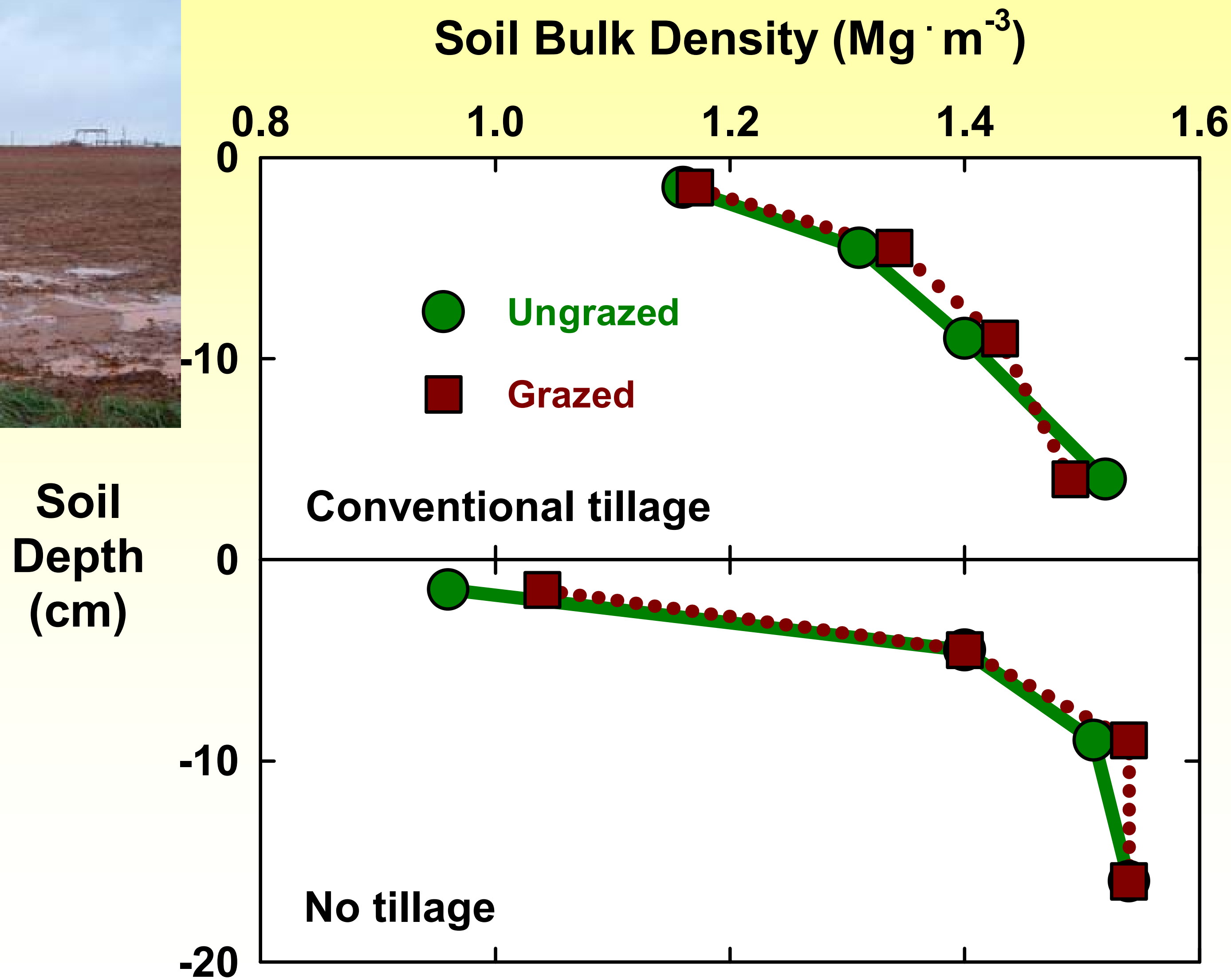
Whether cattle grazed cover crops or not, there was no impact on bulk density under CT and NT, at least at the end of 2 years of management.



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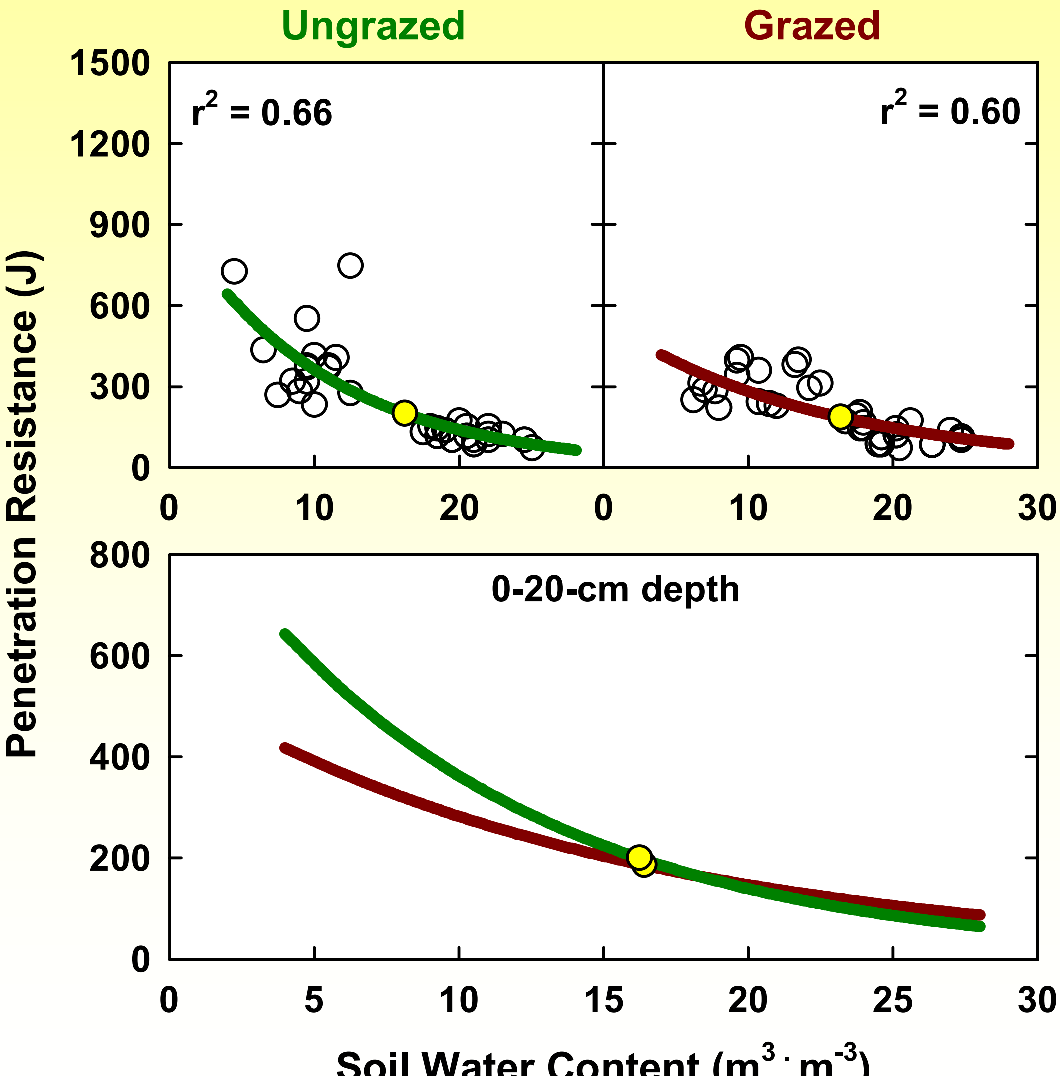

Whether cattle grazed cover crops or not, there was little impact on soil resistance, except at low soil water content.

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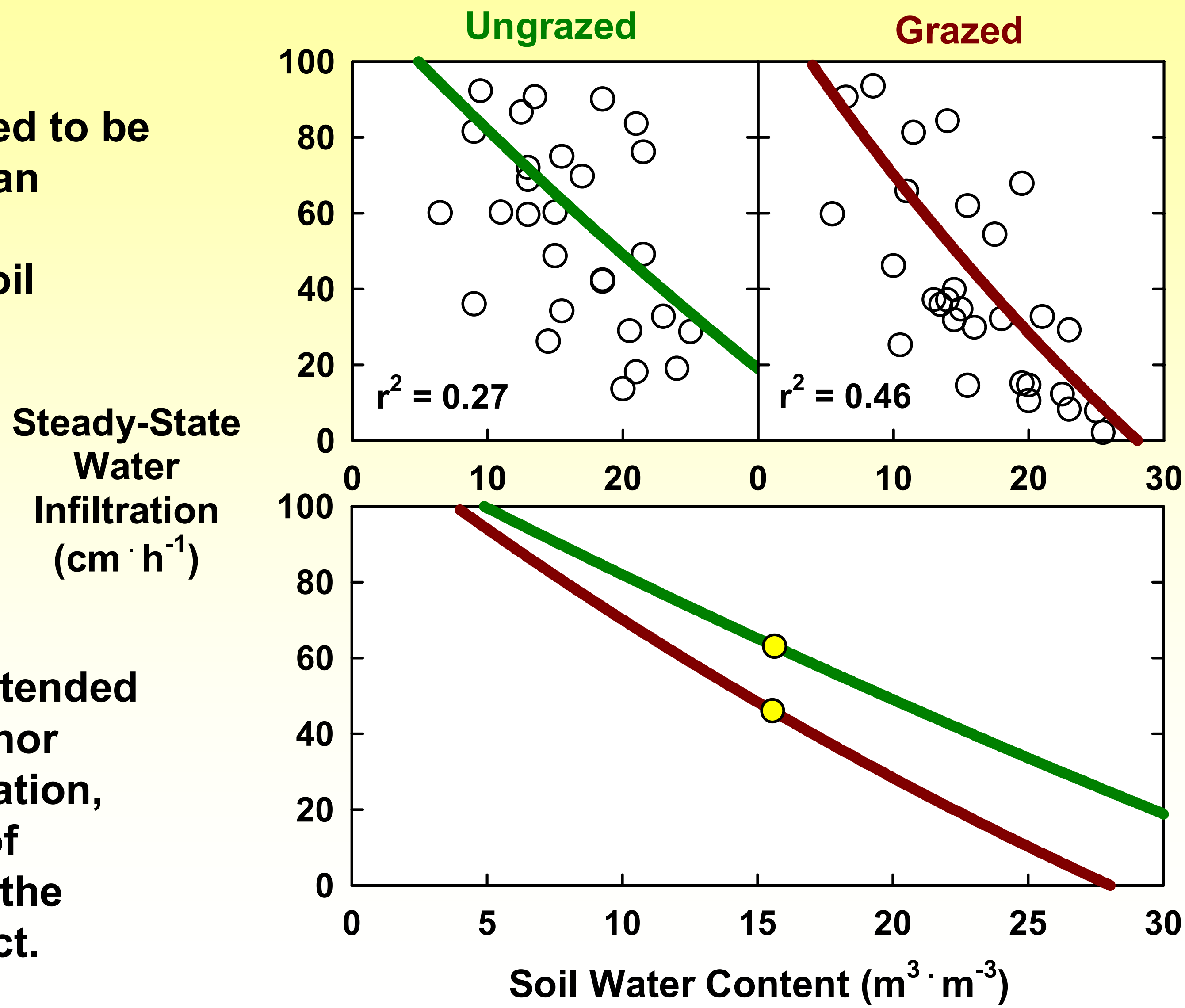
Water infiltration tended to be lower under grazed than ungrazed condition, especially with high soil water content.



Grazing of cover crop tended to have a relatively minor impact on water infiltration, although more years of grazing might change the magnitude of this effect.

- Implications from study -

- No tillage preserved the stratified nature of soil organic and microbial C following long-term pasture, which helped preserve larger water-stable aggregates and maintain high water infiltration.

- Grazing of cover crops was greatly beneficial to production and had only minor or no detrimental effects on soil properties during 3 years.

- Integration of crops and livestock is possible to improve production and environmental quality.

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- Support -

Soils and Soil Biology program of the USDA-NRI, Agr. No. 2001-35107-11126

Georgia Agricultural Commodity Commission for Corn